ANALYSIS OF WOODRAT (NEOTOMA) MIDDENS

FOUND IN WALNUT CANYON, COCONINO COUNTY, ARIZONA

by

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A Thesis

Submitted in Partial Fulfillment

of the Requirements for the Degree of

Master of Science in Earth Science

Northern Arizona University

May 1994

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ABSTRACT

ANALYSIS OF WOODRAT (NEOTOMA) MIDDENS FOUND IN WALNUT CANYON, COCONINO COUNTY, ARIZONA

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Traditionally, elevational plant zonation has been the interpretive framework that has been used in paleobotanical studies. In recent years, however, plant records from woodrat (Neotoma) middens have provided a more complete and accurate record of vegetation history than pollen.

Eight miles east of Flagstaff, Arizona in Walnut Canyon (elevation 6600′) eight middens were removed, analyzed and radiocarbon dated. Vegetation transects were completed directly in front of the rock shelter or crevice from where the midden was removed. Comparisons were made between past vegetation (based on midden components) and current vegetation (based on calculations following the transects).

The plant remains of the middens were compositionally similar to the modern vegetation. The proportion (ranking of taxa) was unusually similar to their proportion in the modern vegetation with the exception of a 3800 year old midden in which conifer needles were more abundant.

ACKNOWLEDGEMENTS

A number of individuals contributed to the completion of this thesis and to whom thanks are due. Dr. Larry Agenbroad provided inspiration and encouragement throughout course and field work while at NAU and provided me with lab space at Bilby Research Center. Dr. Dale Nations provided consistent encouragement, excellent editing assistance and continued long distance support. Dr. Jim Meade and Emily provided assistance in the field. Dr. Richard Hevly helped with references and editing.

The staff at Walnut Canyon deserve special recognition for providing morale and logistical support. Thanks to Superintendent Sam Henderson, Tom Ferrell, Jon Zimmerman and Pam Meck. Nancy Schultz deserves special recognition for continued long distance support and various administrative assistance. Kathy Davis, at the National Park Service Southern Arizona Group Office, (SOAR) deserves thanks for finding funds for radiocarbon dates and valued expertise. Dwayne Collier, also at the SOAR office, deserves recognition for his encouragement to originally pursue this study. Additionally, Southwest Parks and Monuments

Association deserve recognition for funding of radiocarbon dates.

Jon Riketson provided valuable assistance with vegetation transects and Steve Cinnamon provided beneficial ideas and support relative to field work early on in the study.

My parents have supported and encouraged me throughout pursuit of my Master's Degree. My husband, Sean deserves special recognition for his patience and support.

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CHAPTER 1

INTRODUCTION

The history of the late Pleistocene (Wisconsin) and Holocene plant communities of the eastern and northern United States is relatively well known and largely based on the analysis of fossil pollen recovered from lakes or ponds. Such environments are scarce in the American southwest. As a result, history of regional plant communities is not as well documented utilizing pollen recovered from alluvial sediments (Van Devender, 1973). Attention has been shifted to alternative fossil data, particularly plant remains that can be recovered from pack rat (Neotoma spp.) nests (middens).

Philip Wells first called attention to these "paleoenvironmental warehouses" in 1964. The advantages of utilizing pack rat middens to recover information on prehistoric plant communities was first noted in the Mohave and Chihuahuan deserts but now has been extended to many other arid and semi-arid regions (Betancourt, 1984; Betancourt and Davis, 1984; Spaulding, 1983; Spaulding et al, 1983; Van Devender, 1977; Van Devender and Spaulding, 1979; Wells and Jorgensen, 1964; and Wells, 1976).

The advantages of these deposits for reconstruction of prehistoric plant communities are: (1) the plant materials are gathered within a limited radius of the nest; and (2) are preserved in excellent condition, often permitting identification to the specific level.

The location of the midden is the determining factor in whether or not the midden is preserved. Pack rat middens are more likely to be found in rock crevices and shelters, (Finley, 1958). The excellent preservation of these plants is due to the dry climate and the protected shelters where the materials are stored. The midden materials are also strengthened mechanically by amberat (crystallized rat urine) which may act as an allochemic substance retarding decay of delicate plant structures (Wells, 1976). Amberat is water soluble so plant materials are easily recovered from middens for determination of species composition. Modern pack rat middens generally reflect local vegetation, so analysis of a chronological series of pack rat middens allows the reconstruction of local vegetation and climate through time, (Van Devender, 1977). An unexpected outcome of the analysis of pack rat middens was the recognition that the traditional view of altitudinal and latitudinal displacement of plant communities in response to climatic change as suggested by Weaver and Clements (1929) and apparently observed in fossil pollen was inadequate. Simple vertical displacements are unrealistic because plant species respond differentially to changes in climate and do not respond as community units. Plant taxa responding on an individual basis results in the formation of new plant associations as predicted by Gleason (1939).

Elevational plant zonation has traditionally been the interpretive framework used in paleobotanical studies (Betancourt, 1984). Early emphasis was placed on the amount of lowering of vegetation zones during the cooling climate of the Wisconsin. However, in recent years it has become apparent that the Pleistocene vegetation is without a modern representation (Betancourt, 1984).

Plant records from pack rat middens thus provided a more complete and accurate picture of the history of vegetation than did pollen. The first pack rat middens of late Wisconsin age found in the Mohave and Chihuahuan desert were interesting because they contained woodland species plants growing in areas now occupied by desert plants (Wells, 1966). Studies of the plant records obtained from pack rat middens have permitted the reconstruction of the general trends of vegetation history from 10,000 to 30,000 years before present (B.P.).

Specific information for higher elevation plant communities is scarce, particularly from the late Holocene. This study will attempt to evaluate the use of plant data from pack rat middens collected at 7,000 feet in a ponderosa pine forest to reconstruct minor changes of vegetation in response to environmental change resulting from human and climatic impacts during the past 5,000 years at Walnut Canyon National Monument.

CHAPTER 2

DESCRIPTION OF STUDY AREA

Walnut Canyon, located in Coconino County, in north-central Arizona is eight miles southeast of Flagstaff, Arizona.

Location

The location of the study area is on the southern margin of the Colorado Plateau and ranges from 6600 to 6900 feet above sea level. Walnut Canyon was formed by the meanders of Walnut Creek which flowed through the canyon until 1904 when the Lake Mary dam was constructed. The drainage is over twelve miles long. Nichol (1937) observed that the eastern section of Walnut Canyon lies within the pinyon-juniper woodland and the western section is within the ponderosa pine forest (Figure 1). The topographic and microclimatic gradients found in Walnut Canyon are reflected by a rich diversity of plant associations.

In 1906, President Theodore Roosevelt proclaimed the major concentrated area of the cliff dwellings Walnut Canyon National Monument (W.C.N.M.) primarily to protect the dwellings from pothunting and vandalism. Originally, Walnut Canyon was under the jurisdiction of the Department of

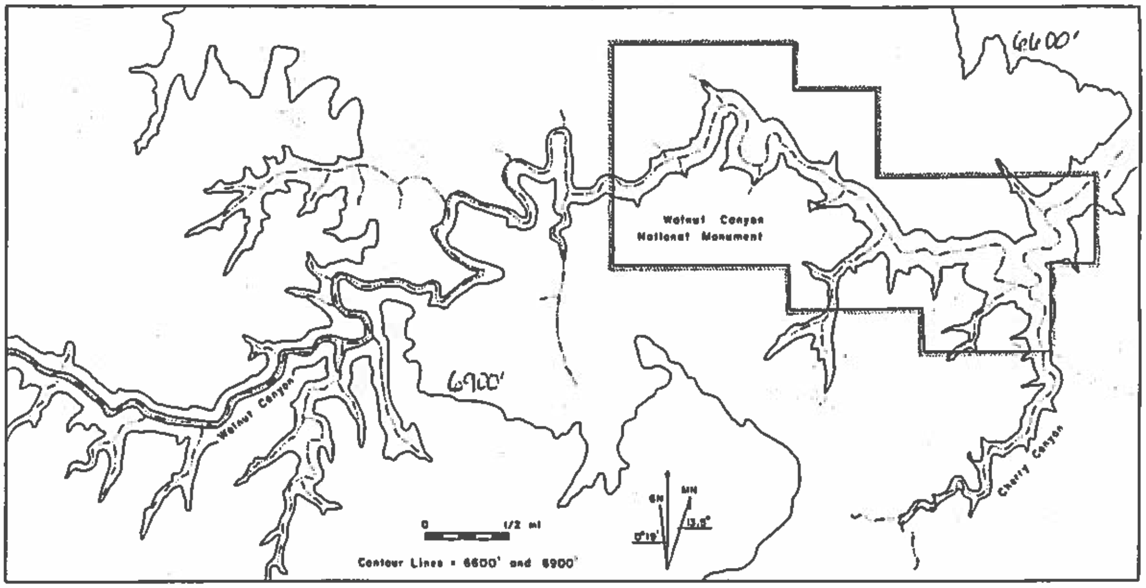

Figure 1. Map of Walnut Canyon illustrating the boundaries of the National Monument. Map by Emily Mead, 1986.

Agriculture, U.S. Forest Service. In 1904, the Forest Reserve built a one room cabin for William Henry Pierce, the Forest Ranger at Walnut Canyon, (Figure 2).

History

On November 30, 1915, Woodrow Wilson issued a Presidential Proclamation declaring Walnut Canyon a National Monument. Walnut Canyon National Monument included 960 acres and remained under Forest Service jurisdiction until 1934. In July of 1934, the management of Walnut Canyon National Monument was transferred to the Department of Interior, National Park Service. Walnut Canyon National Monument was expanded to its present size of 1,920 acres with an inholding of 237 acres by Presidential Proclamation, signed by Franklin D. Roosevelt in September 1938.

Walnut Canyon National Monument is located near the geographic center of Walnut Canyon; the headquarters is located at the end of a paved three mile entrance road which connects to Interstate 40. The monument is bordered by the Coconino National Forest and numerous forest service roads are located on the north and south rims, which provide accessibility into the remote areas of the canyon.

The Colorado Plateau is a significant structural feature of North America, having been uplifted 5,000 to 10,000 feet since late Cretaceous - early Tertiary time.

Figure 2. Ranger Station located on the rim of Walnut Canyon, constructed in 1904 of logs from an abandoned logging camp. Occupied by William and Mattie Pierce from 1904 - 1921, it has been stabilized by the NPS and is standing today. Photo by the author, 1986.

Geology

The region is comprised of plateaus, escarpments, basins and deep canyons. Geomorphic features at Walnut Canyon are typical of those found within canyons located on the Colorado Plateau with the distinguishing characteristics being steep walls and a narrow and meandering course (Figure 3).

The upper stratigraphic unit present at Walnut Canyon is the Permian Kaibab Formation. It is marine in origin, with each member corresponding to a different depositional environment of the Permian sea. Only two of the three members in the Kaibab as described by McKee (1938) are represented in Walnut Canyon. Mollusks, the typical fauna found in this formation were deposited during the maximum advance of the sea and indicate a near shore environment.

Pack rat middens of the study area were found frequently in crevices and cracks that were formed by erosion during the Cenozoic downcutting of Walnut Canyon through the Kaibab Formation. In Walnut Canyon the oldest middens were located within the Kaibab Formation. Cinnamon (1988) also found crevices in the Kaibab Formation to be the preferred location of packrats at Wupatki National Monument, 40 miles north of the present study area. Limestone cliffs are probably the most reliable environment of middens, (Van Devender, 1973).

Figure 3. View of Walnut Creek looking directly down from Monument headquarters on north and south facing slopes. Note relative abundance of trees on north facing slope. Photo credit: National Park Service, 1941.

Pleistocene age middens are remarkably abundant in limestone crevices in southern Nevada (Wells and Jorgensen, 1964).

The lower half of the canyon walls are comprised of the Permian aged Coconino Sandstone. The origin of the Coconino is aeolian as evidenced by the lack of pebbles and multidirectional wedge shaped cross beds. The youngest midden (70 years B.P.) that I located and analyzed was from the Coconino Sandstone in Cherry Canyon, a side drainage of Walnut Canyon.

The rim elevations range from 6,300 to 7,000 feet, while the floor of the canyon ranges from 6,100 to 6,400. Both the north and south rims of Walnut Canyon consist of low, outcropping limestone ledges and terraces with a soil depth of only a few inches near the rim. Differential weathering has caused a change in soil depth grading from a fairly shallow soil on the canyon rims to a deeper accumulation on level terrain. (Figure 4). In general, the soil formation is rather poor in Walnut Canyon and lacks substantial organic content, (Pilles, 1976). The soil cover is deeper on the south rim and the north facing slope, primarily due to an accumulation of organic litter and pine needle duff.

Walnut Creek drains 126 square miles of the the Mormon Mountain watershed (Schyler, 1908).

Figure 4. Differential weathering of Kaibab Formation, the upper geologic rock unit present in Walnut Canyon. Photo by the author, 1986.

Hydrology and Climate

The drainage begins north of Mormon Mountain where water enters upper Lake Mary and flows into lower Lake Mary. The creek bed curves around the northwest edge of Anderson Mesa, turns northeast and cuts through the 350 foot deep canyon. The drainage name changes to San Francisco Wash at the junction with the Rio de Flag, empties into Diablo Canyon and finally into the Little Colorado River.

The Santa Fe Dam was built between 1883 and 1886, (Shimer and Shiner, 1910) of limestone quarried from the site (Figures 5 and 6). The dam is located at the eastern boundary of the monument and is now on private land. It served as a reservoir and in years of high precipitation the dam would overflow and the Walnut Creek drainage would have water in the bottom of the canyon (Figure 7).

The Flagstaff area received a mean annual precipitation of 20.27 inches from 1889 to 1951 (Sellers and Green, 1960) and 19.80 inches from 1950 to 1970. The Walnut Canyon weather varies from Flagstaff weather especially with individual storms that may be more intense or may pass by the Monument. Most of the summer precipitation in the Flagstaff area occurs in early July through September in the form of summer monsoons.

Colton (1958) conducted a twenty year study of local precipitation patterns and the effects of landforms on local weather. Results of his study found that annual

Figure 5. Santa Fe dam, constructed between 1883 and 1886 is located immediately east of the present Monument boundary on private land. The dam is being maintained by the current owner and still standing. Photo credit: Paul Beaubien, April 16, 1939.

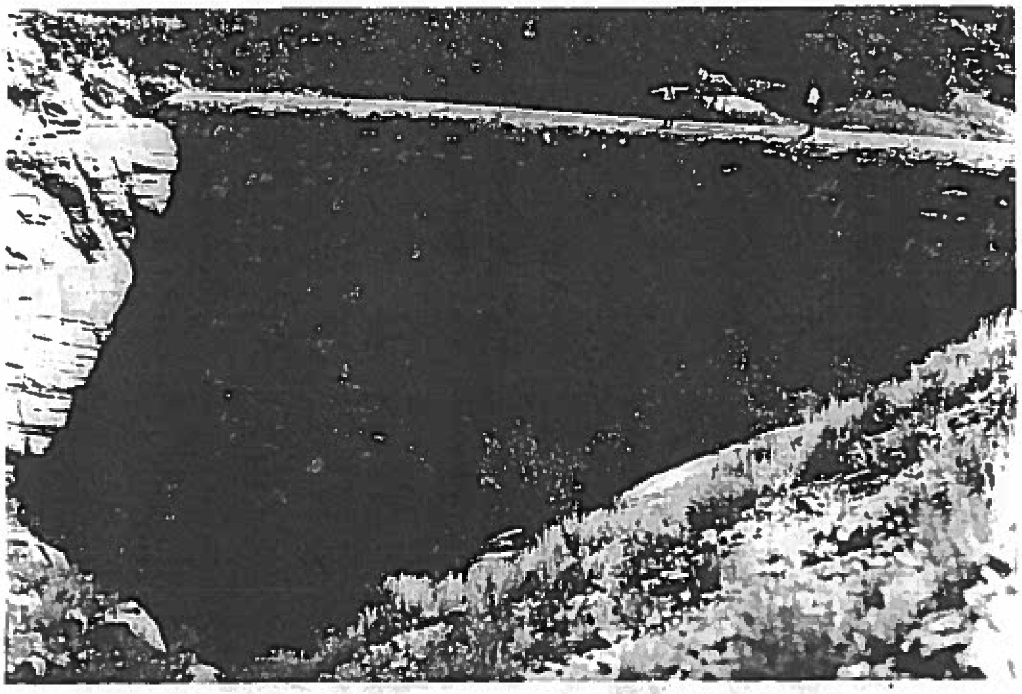

Figure 6. Close-up view of Santa Fe dam showing limestone which was quarried at the location. NPS custodian Paul Beaubien is standing with arms outstretched. Photo credit: Eiehl, 1935.

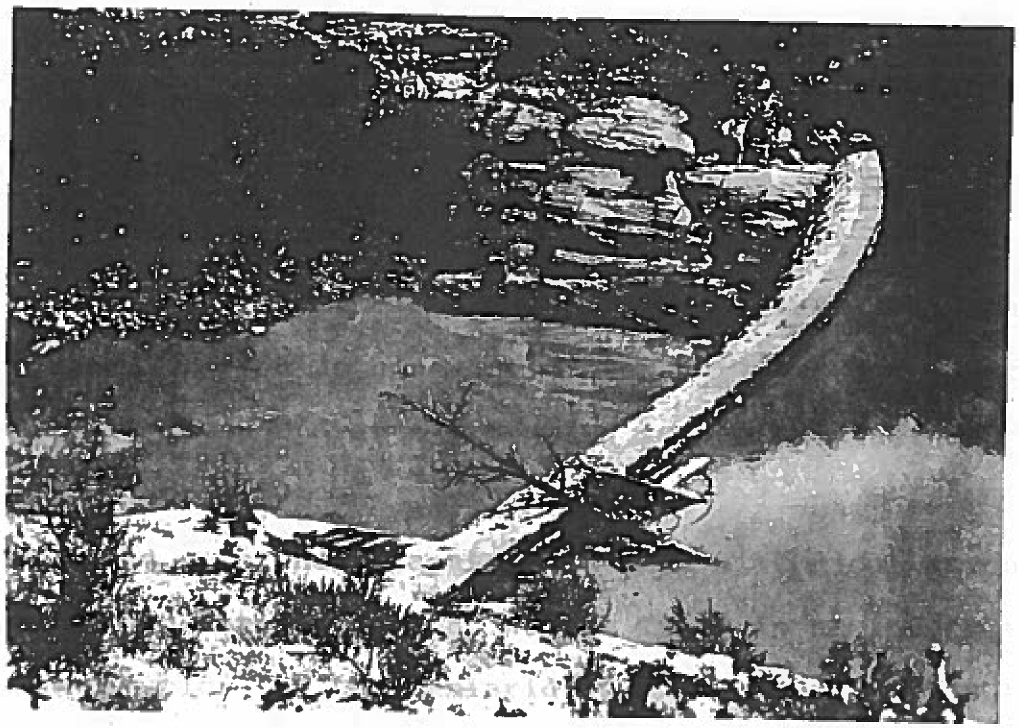

Figure 7. Overflow of water over the Santa Fe dam into Walnut Creek. Note cross-bedding of Coconino Sandstone in background. Photo credit: Paul Beaubien, April 16, 1939.

precipitation patterns in the Ponderosa pine zone varied from approximately 16 - 23 inches per year and in the juniper zone from 11 - 12 inches per year. In the areas just east of the San Francisco Peaks, he observed that precipitation fluctuated from north to south. Colton attributed this to the "rain shadow" effect caused by the San Francisco Peaks and Anderson Mesa. Snowfall is less consistent, the average amount received is 58 inches, but an excess of that falls in heavy winters.

Walnut Canyon is influenced by a similar precipitation pattern, with the combination of air currents off Anderson Mesa and canyon updrafts producing localized afternoon thundershowers.

Based on a photographic study and historical accounts it has been determined that Walnut Creek is an intermittent stream, typical of the semiarid southwest (Brian, 1985).

Prior to 1905, water from snowmelt and summer thunderstorms flowed into Walnut Canyon for only a few weeks. Measurable amounts of water entered Walnut Canyon over the Lake Mary Dam in wet years. However, the total amount probably declined following the completion of upper Lake Mary in 1941. Upper Lake Mary dam was raised 12 feet in 1951, increasing the reservoir depth and the total capacity of the dam. Today, moisture within the drainage and in scattered basins is the result of rainfall and runoff on the steep canyon walls.

Fauna

The varied topography and vegetation within Walnut Canyon make it ideal habitat for several hundred species of animals; including birds, mammals and reptiles. Commonly observed birds include the Stellar's jay (Cyanocitta stelleri), Townsend's solitaire (Myadestes townsendi), turkey vulture (Cathartes aura), red-tailed hawk (Buteo jamaicensis), mountain bluebird (Sialia currucoides) and canyon wren (Catherpes mexicanus). The northern pygmy owl, spotted owl, prairie falcon and goshawk have been observed consistently by the author.

During the winter, Stellars jay, nuthatches, creepers, titmice, chickadees and grosbeaks are the most commonly observed birds. Throughout the summer, tanagers, hummingbirds, warblers and towhees frequent the canyon.

Small mammals that are easily observed include the desert cottontail (Sylvilagus audubonii), black-tail jack rabbit (Lepus californicus), rock squirrels, (Spermophilus variegatus), deermouse, (Peromyscus maniculatus), and the Abert's squirrel (Sciurus aberti). Three species of woodrats currently inhabit the Walnut Canyon drainage, Neotoma albigula (white-throated woodrat) N. mexicana (Mexican woodrat) and N. stephensi (Stephen's woodrat).

The gray fox (Urocyon cinereoargenteus) has been observed raising young in a den within the monument. Bobcats (Lynx rufus) and ring-tailed cats (Bassariscus astutus) have left their tracks and scat as a reminder, that they, too, inhabit the canyon.

Large mammals observed while completing field work include mule deer (Odoceoileus hemionus) pronghorn antelope (Antilocapra americana) elk (Cervus canadensis), coyote (Canis latrans), and mountain lion (Felix concolor). Evidence of black bear (Ursus americanus) in the form of scat, has been seen along the canyon bottom.

In the summer months, reptiles commonly seen basking in the sun include the western fence lizard (Sceloporus) and the "horny toad" lizard (Uta sp.). The gopher snake is seen on the rim of the canyon and coral snakes (Micurus sp.) and rattlesnakes (Croatalus) within the canyon.

Archaeology

Walnut Canyon was inhabited in the years A. D. 1100-1250 by the Sinagua Indians. Literally meaning "without water" in Spanish, this culture was named by Dr. Harold S. Colton due to the dry farming techniques the Sinagua practiced. Sinagua tradition is characterized by paddle and anvil produced brownware ceramics, lack of indigenous decorated (painted) pottery and extended burials. The Sinagua are considered to be a prehistoric tribe, the term "prehistoric" meaning prior to a written record.

Sinagua pre-history is considered in two major periods: pre-eruptive and post eruptive, relative to the eruption of Sunset Crater, a cinder cone 22 miles to the north.

Different dates for the eruption of Sunset Crater have been proposed; and archaeological and geological evidence indicates cinder eruptions occurred episodically between A. D. 1064 and A. D. 1250 (McGregor, 1936; Pilles 1976).

The cinder cover forms a broad north/south band along the georaphic area of the eastern flanks of the San Francisco Peaks to the Little Colorado River. This so-called "black sand" has formed the basis for the development of Colton's "land-boom" theory.

Harold Sellers Colton's theory postulated that neighboring Indian tribes moved in on the Sinagua to begin farming the newly deposited moisture-retaining mulch (Colton, 1932). The long-range effects of a moderate ash fall may ultimately be beneficial to agriculture, especially if that area escapes erosion.

Wilcox (1959) reports that most soils are chemically and physically improved by an ash fall, similar to that of normal soil, except for low nitrogen content and low percentages of chemically combined water and organic material.

The negative effects of an eruption can be significant, too. Volcanic fumes, especially sulfur dioxide, fluorine and chlorine are expelled for a considerable time after an eruption and low concentrations of these are damaging to plants (Gilman, 1976).

Eight phases have been proposed to cover the Sinagua sequence. The pre-eruptive phases consist of the Cinder Park phase A.D. 500-700, the Sunset phase of A.D. 700-900, and the Rio de Flag phase of A.D. 900-1066. Post-eruptive time is divided into the Angell-Winona-Padre phase of A.D. 1066-1130, the Elden phase of A.D. 1130-1200 and the Turkey Hill phase of A.D. 1200-1300. The northern Sinagua sequence terminates with the Clear Creek phase A.D. 1300 (Pilles, 1976).

Walnut Canyon was occupied during the Elden phase. 300 rooms (cliff dwellings) have been located and 240 archaeological sites have been recorded (Baldwin and Bremer, 1986) (Figure 8).

Sites vary from one-room stone enclosures (field houses), subsurface homes (pit houses), multiple-room surface dwellings (pueblos), rooms beneath overhangs (cliff dwellings), and structures atop rock "islands" (forts). Distinctive walls constructed of limestone blocks have been recorded within the monument, and are interpreted as defensive (Baldwin and Bremer, 1986) (Figure 9).

Rock alignments along shallow washes are often found in association with the field houses. Today these "check dams" or terraces are filled with sediment and organic debris. These dams were useful in the dry farming techniques practiced by the Sinagua in growing their crops of corn, beans and squash.

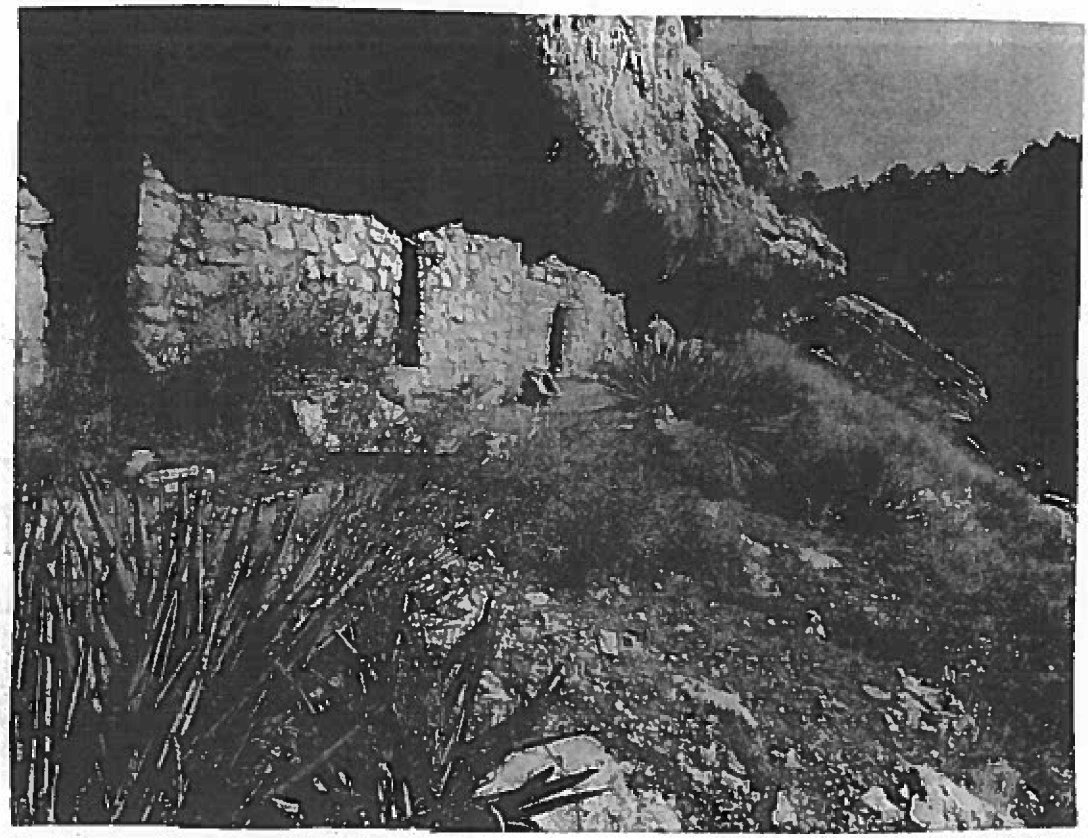

Figure 8. Sinaguan cliff dwelling, occupied A.D. 1100-1250. This dwelling is located on the Island Trail, within Monument boundaries and is facing south. Note xeric vegetation on the south facing slope as compared to slope of opposite canyon wall in the background. Photo credit: National Park Service, 1966

Figure 9. Limestone blocks in a defensive wall, constructed by the Sinagua Indians. Signboard measures 6 by 8 inches across. Photo credit: Anne Baldwin, 1986.

Paleoclimate

During the Sinagua occupation, water became an increasingly important resource. From A.D. 700 to A.D. 1100 there was increased summer rainfall, greater erosion and shorter, milder winters (Schoenwetter and Dittert, 1968; Hevly, et al, 1979; Cinnamon, 1988). These shorter winters increased the growing season and also the length and severity of the spring drought. Water control methods were used and it is also evident from the dwelling locations that the population shifted in response to changing environmental pressures.

The twelfth and thirteenth centuries were crucial to Sinagua prehistory. Summer rainfall and erosion were both dominant but most of this time period was drier than present (Schoenwetter and Dittert, 1968).

Vegetation

The vegetation zones in the Southwest are arranged vertically in the altitudinal moisture gradient, with drier desert communities at lower elevations with woodlands and forests at higher elevations. This phenomenon was originally described by C. Hart Merriam in 1889.

The Flagstaff area reflects much of the diversity described by Merriam. A semi-arid, shrub and grass dominated desert or upper Sonoran zone distinguishes both the Verde Valley to the south and the Little Colorado River valley to the northeast. The other extreme, a spruce-fir or

Hudsonian zone forest topped by an Alpine-Tundra zone occupies the upper slopes of the San Francisco Peaks.

Within Walnut Canyon, three life zones are represented by dominant trees. The Transitional, Canadian and upper Sonoran zone are represented by ponderosa pine, douglas fir, and juniper (Figure 10).

Joyce (1974) completed an ecological and taxonomic analysis of the flora of the Walnut Canyon drainage. Using line-intercept transect data, percentage values were calculated for the cover of total vegetation sampled. From these percentage values, the relative density, frequency, dominance and importance values were calculated. Four distinct plant communities were found to exist within the drainage. (Table 1).

Table 1
Vegetative Communities within Walnut Canyon

North Rim (south-facing)	*Pinus edulis* *Juniperus osteosperma*
South Slope (north-facing)	*Pseudotsuga menziesii* *Pinus ponderosa*
North Slope	*Poa fendleriana* *Artemisia frigida*
Canyon Bottom	*Acer negundo* *Juglans major*

Differences in plant species composition are evident between Walnut Canyon National Monument and the rest of the drainage. These differences in vegetation could probably

Figure 10. Ponderosa pine/Douglas fir on west facing slope, Arizona black walnut on canyon bottom, pinyon-juniper on east-facing slope. Photo by the author, 1986.

be attributed to two factors. The first is that the area around Walnut Canyon National Monument has been in a fairly constant state of disturbance from repair and ruins stabilization work. Visitor impact provided a frequent source of new seed from distant areas and the disturbed ground has provided a receptive habitat for the establishment of new species.

The second factor is that the Sinagua culture may have introduced new and different species. This theory was initially explored by Clark (1968) whose results indicated that it was not the Indians who had such a tremendous impact directly on introducing seeds and plants, but that their dwellings may have.

Clark suggested that these dwellings may have provided natural catchments for wind-blown seeds, homes for seed carrying animals and disturbed conditions for native vegetation. He felt that the plants associated with these areas were maintained simply because they were freed of competition, since they might not have survived in this vegetation zone if there had been competition.

CHAPTER 3

PACKRAT (NEOTOMA) MIDDENS

The genus Neotoma includes about twenty species of rat-like rodents with a wide distribution in North and Middle America, (Wells, 1976). Nine species occur across the United States, ranging in habitat from deciduous forests to hot and dry deserts, (Van Devender, 1973). The white-throated, Mexican and Stephen's woodrat live within the Walnut Canyon drainage. These neat, large-eyed herbivores range in size from 25-45 cm. and in weight from 95-595 grams. All of these species share the same habit of collecting a variety of materials from their immediate surroundings, hence the name "packrat". The materials that they collect are added to debris in their den or house.

Middens

Woodrat dens are either conical accumulations of debris in open sites or material placed in a wide variety of areas ranging from caves, crevices and vertical cracks to old buildings. White-throated woodrats build houses as high as four feet, with several entrances that lead to the nest.

Finley (1958) defined living units of the woodrat as: "the den is any large, outer shelter enclosing living chambers and passages; a house is a kind of a den constructed by the occupant out of gathered materials in order to provide shelter, and the nest is a soft, fibrous resting place located in a chamber. A second type of den is a natural rock shelter with only a few gathered materials including food, debris and fecal pellets."

The outer covering of houses can often appear as a haphazard array of sticks of various shapes and sizes. This layer helps to securely anchor the complete structure and also serves as a protective shell over the entire house interior. The interior is comprised of the midden which is perforated by interconnected passages and chambers.

The habit of constructing these dens has great adaptive values for the woodrat. A woodrat's mode of existence centers on a secure shelter and the use of spiny cacti or thorny shrubs helps to protect the rat from predators.

In hot environments, there is an advantage of slightly increased relative humidity and reduced air temperature (due to shading of the soil) that is important for survival. In cold environments, the fibrous nests provide additional insulation and when temperatures drop too low for normal foraging, the food cache allows the woodrat to remain in the den (Van Devender, 1973).

The woodrat benefits from the minimum home range that sustains the woodrat. This serves to minimize predation and maximize efficiency of energy expenditure used in foraging.

Woodrats have few physiological adaptations that aid in their survival in environmental extremes. They can eliminate plant resins and harsh chemicals from their bodies through a renal mechanism (Lee, 1963). Woodrats are not as well adapted to the desert as rodents like the kangaroo rat (Dipodomys sp.) which produce water metabolically. Woodrats do not need liquid water and are thus dependent on fresh vegetation for their daily water requirement.

Juniper is of primary importance to Stephens woodrat as a consistently available source of food and water. One-seed juniper in the Flagstaff area averages fifty-five percent water by weight in winter. The leaves of this plant are fairly low in fat and proteins but high in carbohydrates (Vaughn, 1980).

Three habits are present to various degrees in all species of Neotoma that are responsible for determining their ecological niches. These are: climbing ability, collecting materials for den construction and a diet of predominantly leafy/succulent vegetation. Woodrats eat a variety of plant food, depending upon availability, but nearly always the foliage of trees, shrubs and forbs is the dominant food throughout most of the year (Finley, 1958).

Woodrats do not collect plants in proportion to relative abundance because biases exist in the preferred food, depending on the species of woodrat. This is especially true for N. stephensii who has a strong preference for one-seed juniper. In canyons, where various species occur at different elevations, changes in altitudinal distributions of preferred dietary plants may cause overlap of species (Cole, 1982).

Materials and Methods

Vegetation was recorded along fifty meter transects to determine the relative abundances of plant species. Transects were measured directly in front of midden location. Vegetation characteristics were recorded in August and September, 1985 when diversity of species is at its peak. Relative density, percentage of ground covered, importance value and relative dominance were calculated. Current vegetation and plant macrofossils found in middens could then be compared and contrasted.

Approximately 45 species of plants were identified from packrat middens found within the Walnut Canyon drainage. This data is found within Appendix A, list of plant species. The plant parts were identified by comparison with the reference collection of pressed plants at the Walnut Canyon National Monument herbarium and those at the Deaver Herbarium at Northern Arizona University.

References use for plant identification included: Arizona Flora by Kearney and Peebles (1951), Grasses of the Southwestern United States by Frank Gould (1951) and Seed Plants of Northern Arizona by W.B. McDougal (1973).

Investigation into the Walnut Canyon drainage yielded many potential midden sites. Further investigation revealed potential sites within the monument's boundary had been impacted by early NPS stabilization work on Sinauga ruins. Collecting was then restricted to areas outside of the boundary of the monument, except for the last midden which was collected on the Island Trail, within the monument. A collecting permit was applied for and received from the Regional Archaeologist, Western Regional Office, National Park Service.

Numerous middens were encountered and the factors that determined if the midden was collected or not were: location, associated plant assemblages, and how old the midden appeared. One reliable indicator of age of a midden is the odor. Older middens (in the range of 3,000 to 25,000 years) have a very "sweet" smell, compared with younger middens (approximately 50 to 800 years) which have a musty odor.

Older middens may be layered with obvious and distinct stratification. Collecting of middens was done carefully to avoid mixing of stratigraphic units within middens. In cases where an indurate midden was stratified, individual layers were collected and bagged separately. Eight middens were collected, from xeric localities atop limestone ridges to protected areas in riparian habitat.

Plant macrofossils or fecal pellets from each midden were removed and submitted for radiocarbon dating. The material was weighed and shipped in an airtight container to Beta Analytical Laboratory in Florida. Two grants for $800.00 each provided the funding: one from the Southern Arizona Group Office, National Park Service and one from Southwest Parks and Monuments Association, Tucson, Arizona. Refer to Table 2 for additional radiocarbon information.

Preparation involved labeling the sample and then soaking the middens in water for ten days. Following the soaking procedure, all of the samples were screened through a 20-mesh soil sieve and air dried.

Table 2
Midden Locations and Radiocarbon Dates

Midden #	Location	C14 Date	Material Dated
Midden #1	Cherry Canyon	70 +/- 60 BP	Fecal Pellets
Midden #2	Fifth Fort (E)	3800 +/-70 BP	JUMO, PSME
Midden #3	Fifth Fort (E)	3430+/-70 BP	PSME
Midden #4	Fifth Fort (W)	1960+/70 BP	PSME
Midden #5	Fifth Fort (W)	1950+/-70 BP	Fecal Pellets
Midden #6	First Fort (N)	3660+/-80 BP	JUMO, PIED
Midden #7	First Fort (W)	1880+/-100 BP	Fecal Pellets
Midden #8	Island Trail	760+/-60 BP	Fecal Pellets

JUMO *Juniperus monosperma*

PSME *Pseudotsuga menziesii*

PIED *Pinus edulis*

Midden Locations

The locations of all middens are shown in Figure 11. Midden number one was collected in Cherry Canyon, a side drainage of Walnut Canyon (Figure 11). The alcove in which this midden was collected is considered an archeological site and has very interesting rock art associated with it. The natural history of this area is distinctive because the author has observed spotted owl (Strix occidentalis), javelina (Dicotyles tajacu) and mountain lion (Felix concolor) in that drainage.

Nine spotted owl pellets were collected within close proximity to the alcove. The pellets were analyzed for pertinent natural history information. The pellets contained bones of: Stephen's woodrat (Neotoma stephensi), Mexican vole (Microtus mexicanus), deer mouse (Peromyscus maniculatis) and western harvest mouse (Reithrodontomys megalotis). Bones found in the pellets included skull and various leg bones.

The outer covering of the midden in Cherry Canyon appears as a haphazard array of sticks and pine cones (Figure 12). A large indurate midden (midden number one) was removed from beneath a Coconino Sandstone rock ledge.

Middens number two, three, four and five were located in rock shelters (forts) atop a limestone ridge, in a xeric environment (Figures 13 and 14). There are archeological sites near these rock shelters. Based on preliminary field

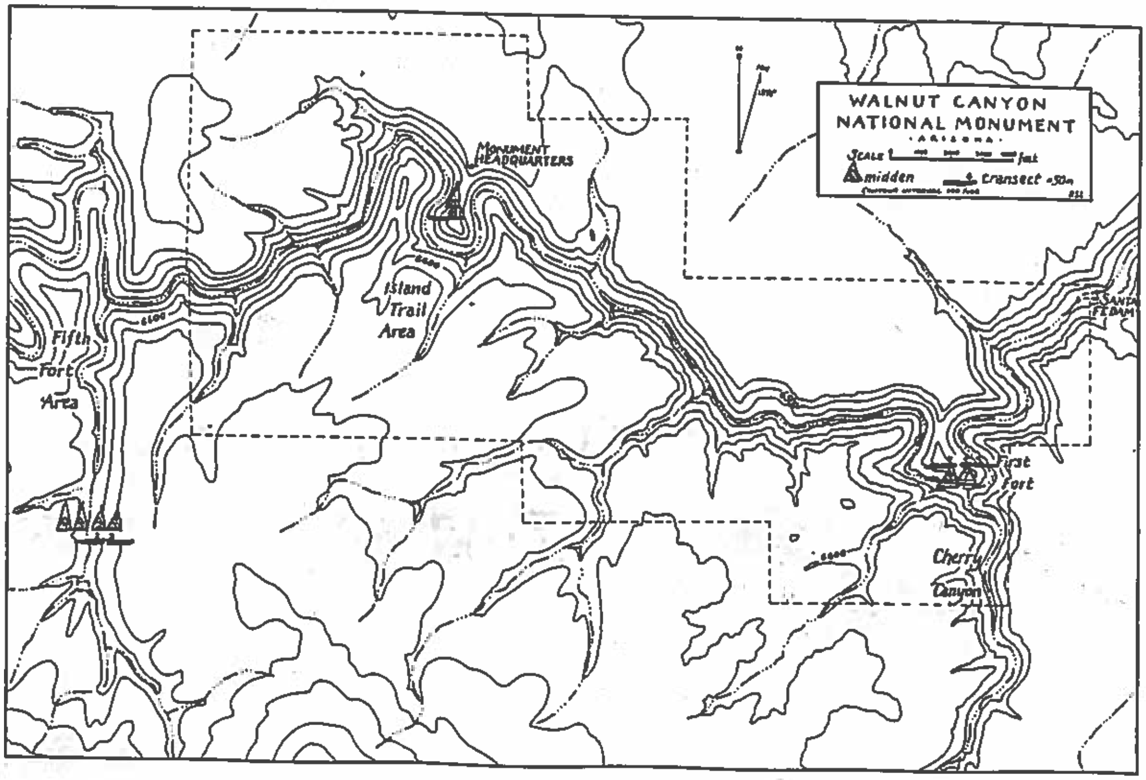

Figure 11. Map of Walnut Canyon showing midden locations and vegetation transects. Map by D. Livingston, 1986.

Figure 12. Removal of woodrat midden in Coconino Sandstone, located in Cherry Canyon, southeast of Monument headquarters. Photo credit: Tom Ferrell, 1986.

Figure 13. Rock shelter within Walnut Canyon drainage, Fifth Fort, west of Monument boundary. Photo credit: Anne Baldwin, 1986.

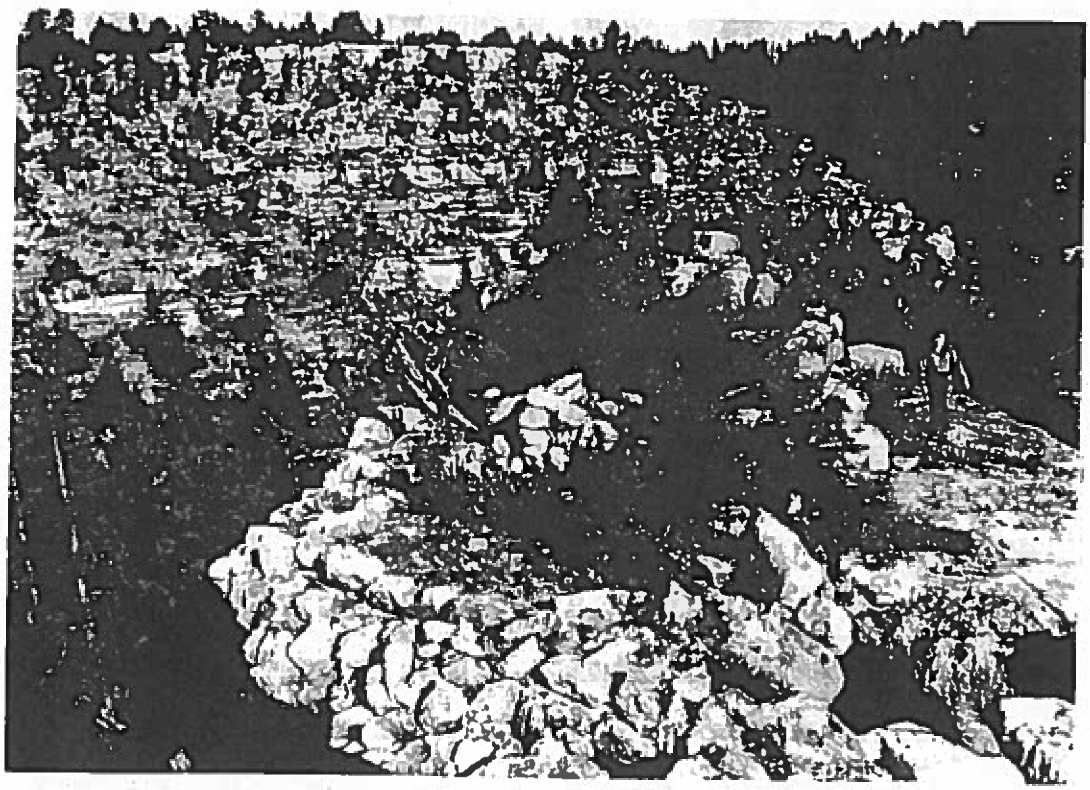

Figure 14. Limestone ridge near Fifth Fort, west of the Monument boundary. Photo credit: Mike Bremer, 1986.

investigations it was thought these middens were very old when first encountered.

The middens had a "sweet", rather than musty odor, and had to be removed from the ceiling of the rock shelter where they were discovered (Figures 15 and 16). Samples were taken from two separate rock shelters, one facing east and the other facing west. These middens were stratified and samples were extracted from separate layers for dating purposes. Midden number two was the oldest in the study with a radiocarbon date of 3800 +/-70 years B.P.

First Fort, 3.5 miles east of monument headquarters, is outside of the monument boundary. Two middens were collected from this area. The vegetation on the rim and ridge tops is characterized by pinyon pine (P. edulis) and juniper (Juniperus monosperma and J. osteosperma). The canyon walls are not as steep as in the proximity of the visitor center and Walnut Creek has created several wide meanders (Figure 17). The vegetation varies greatly, when comparing the riparian bottom of the canyon, to the rocky shelter on the shallow slopes. Two samples were extracted from two midden locations, one within a shallow limestone outcrop above the canyon bottom and the second from a rock outcrop closer to the bottom of the canyon (Figure 18).

Midden number eight was collected adjacent to a cliff dwelling, in an area that could be classified as "impacted" or "disturbed"; directly off of the Island Trail, a paved

Figure 15. Removal of 3800 year old midden from rock overhang in the Fifth Fort area, west of the Monument boundary. Photo credit: Mike Bremer, 1986.

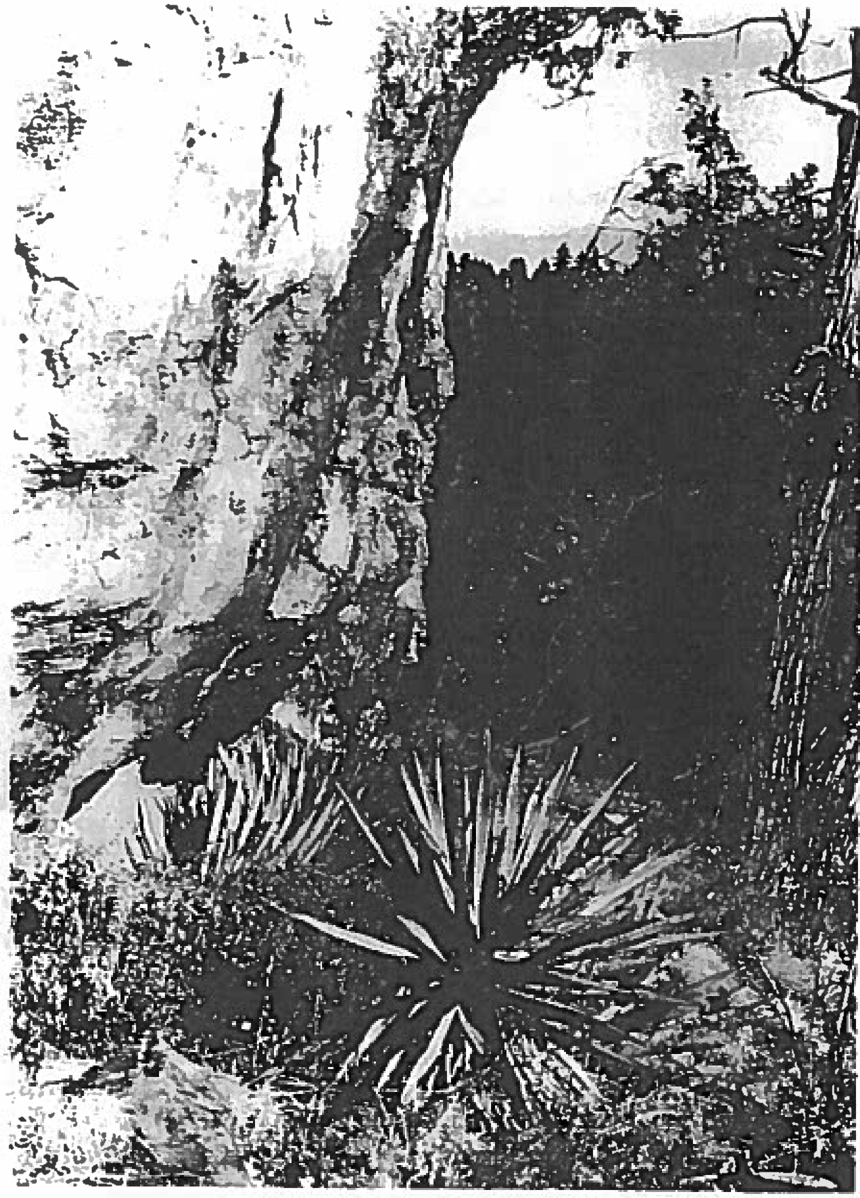

Figure 16. Exterior of midden location at Fifth Fort illustrating dominant vegetation. Note dominant xeric vegetation in foreground and close proximity to pine and fir trees. Photo by the author, 1986.

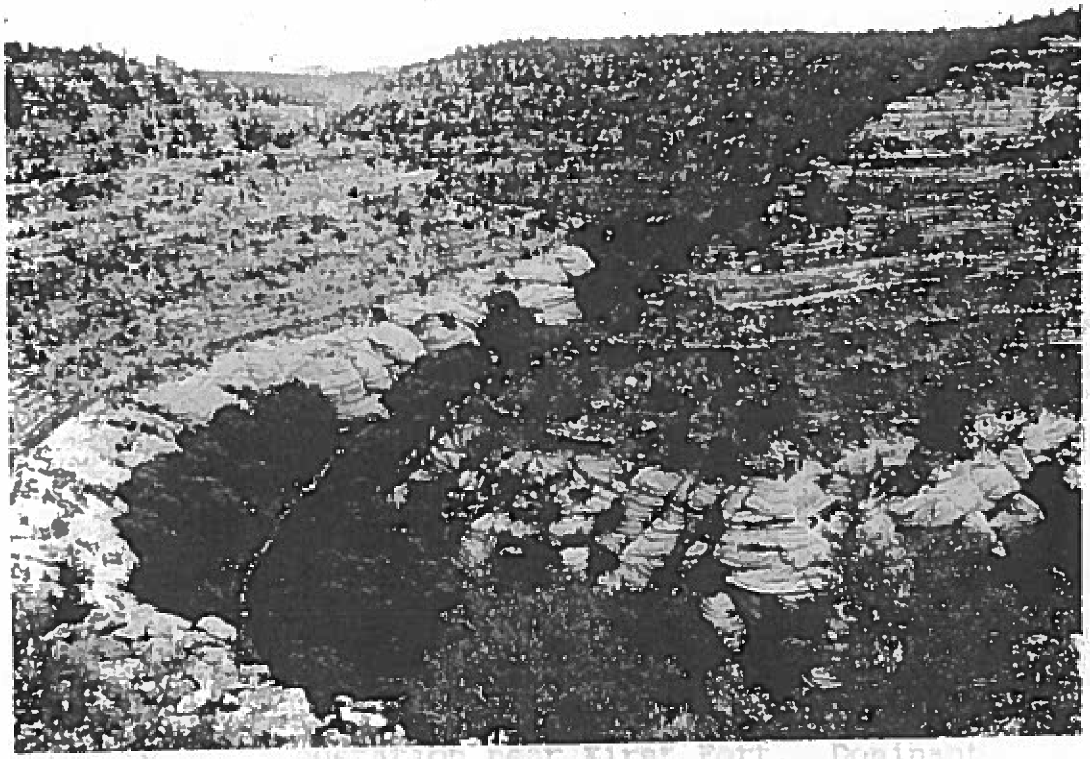

Figure 17. Meander in creek bed near First Fort. Note Arizona black walnut trees and New Mexico locust trees along canyon bottom. Photo by the author, 1986.

Figure 18. Vegetation near First Fort. Dominant vegetation is a mix of pinyon-juniper and rabbitbrush. Photo by the author, 1986.

self-guiding trail within Monument boundaries, (Figure 19). This midden had numerous thorny stickers from hedgehog (Echinocereus triglochidiatus) and pricklypear (Opuntia fragilis) serving to protect the entrance from predators. The overall appearance of the vegetation in this area is distinctive, it is a southern exposure with more cacti and shrubby composites.

Interpretation of Results

Comparisons were made between the dominant vegetation recovered from the midden as contrasted with the dominant species growing in the area. For midden number one (located in Cherry Canyon)the dominant herbaceous vegetation within 30 meters of the woodrat midden was mountain muhly, virginia creeper, meadow rue and goldenrod. The overstory woody vegetation included wild rose, Arizona black walnut, New Mexico locust and occasional Gambel's oak (Quercus gambelii). One-seed junipers grow within 40 meters of the midden site. The highest percentage of vegetation found in the midden was one-seed juniper. It appears as though woodrats utilizing this nest were consistently exceeding normal foraging distance of 30 meters, based on apparent dietary preference for one-seed juniper. Based on preliminary field determinations and due to the high potential for flooding, it was thought the age of this midden would not be very old. The radiocarbon date verified this assumption, as the date was 70 years B.P.

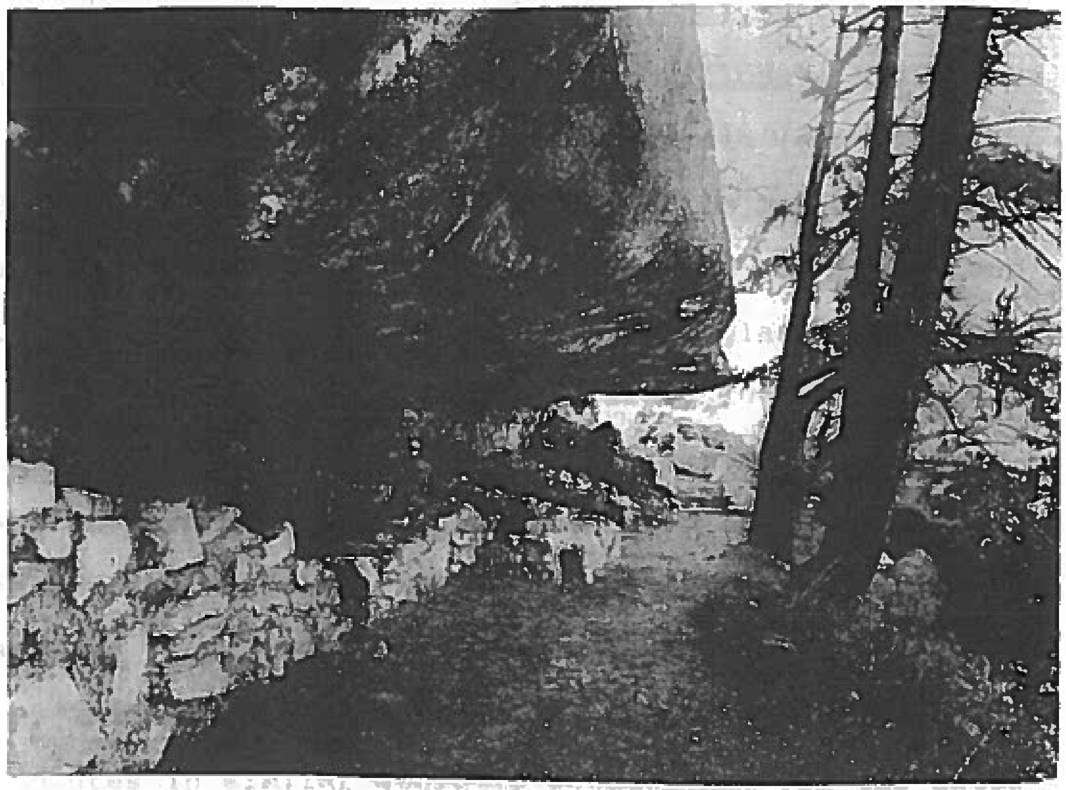

Figure 19. Cliff dwelling along Island Trail, within Monument boundaries, facing west. Photo credit: National Park Service, 1966.

The location of Fifth Fort is 0.25 miles from the Monument headquarters area, west of the Monument boundary. In the area where middens from Fifth Fort were collected the dominant herbaceous vegetation is: buckwheat (Erigonum jonesii), mutton grass (Poa fendleriana), vetch (Astragulus humistratus) and aster (Heterotheca villosa). Blue yucca (Yucca baccata), snakeweed, and artemisia (sage) are abundant within close proximity. Within the midden, most of the material was Douglas fir (Pseudotsuga menzesii) and pinyon pine Pinus edulis) needles. Douglas fir and pinyon pine are found in the Fifth Fort area, 100 yards from the midden site. Two large middens were removed and four samples were dated. Results indicated the east-facing shelter had the oldest dates of any found: the dates were 3800 +/- 70 years B.P. and the second layer was 3430 +/- 70 B.P. Middens four and five were collected from west-facing exposures in similar geologic formations, yet the dates were younger, 1950 +/- 70 B.P.

Midden number six was collected from the First Fort area, outside of the Monument boundary. The herbaceous vegetation is dominated by four-wing saltbush (Atriplex canescens), buckwheat (Erigonum jonesii) various shrubby composites (snakeweed, Artemisia) and bunch grasses (Bromus sp.). The woody vegetation within this 3660 +/- 80 B.P. year old midden was comprised of pinyon pine and one-seed juniper. Additional species identified included wild rose

(Rosa arizonica) barberry (Berberis fremontii) and pricklypear cactus (Opuntia fragilis); species that currently are found in that location.

Midden seven was collected from an area with the highest percentage of vegetative cover, 85.6%. The floor of the canyon is relatively wide. Dominant vegetation is rabbitbrush (Chrysothamnus nauseosus), blue grama grass (Bouteloua gracilis), four-wing saltbush (Atriplex canescens) and tansy mustard (Descurainia pinnata). This transect also included rice grass (Oryzopsis hymenoides), an edible grass used by Native Americans. The date on this midden was 1880 +/-100 years B.P. and the highest percentage of vegetative material was one-seed juniper. The most common trees within the immediate area are predominantly one-seed juniper and pinyon pine.

The midden collected from an impacted area, midden number eight, had dominant vegetation composed of: mountain mahogany (Cercocarpus betuloides), wild rose (Rosa arizonica), serviceberry (Amelanchier utahensis), sagebrush (Artemisia dracunculus) and yucca (Yucca baccata). Other shrubs such as snowberry (Symphoricarpos oreophilus), elderberry (Sambucus coerulea), bunch grasses such as mutton grass (Poa fendleriana) and blue grama grass (Bouteloua gracilis) were represented. A very small amount of conifer needles were screened out of this sample.

Surmising from vegetation analysis, it appears as though the woodrats were either exceeding normal foraging distance 3800 years ago, or the proximity of Douglas fir and pinyon-pine were closer to the rock shelter area. Based on the vegetative analysis of eight woodrat middens, the major component of seven of the eight middens was juniper needles. Knowing the woodrat's dietary preference for juniper, it appears as though they are consistently willing to forage outside of a normal foraging distance of 100 yards in order to satisfy that preference.

From the results of this study, it appears as though the abundance of plants such as Yucca baccata, snakeweed rabbitbrush, sage and buckwheat, have increased. It is noteworthy that in the three oldest middens, Yucca baccata is not a component, yet was found in small amounts in the younger middens. There appears to have been little, if any Yucca sp. growing in Walnut Canyon 3880 years ago. It is possible the Sinagua, who utilized the Yucca sp. for many purposes, may have introduced and cultivated it, much as they did corn, beans and squash.

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APPENDIX A

VEGETATION TRANSECT DATA

Table 3
Cherry Canyon Transect Data
Refer to Fig. 11
Total Vegetative Cover = 52.9%

Rank by Cover Species	% cover total veg.	% cover total legth	% freq.	Relative Density
Muhlenbergia montana	26.0	14.1	40	20
Parthenocissus inserta	10.3	4.9	30	7.3
Thalictrum fendleri	5.3	3.0	20	4.16
Solidago sparsiflora	3.6	2.2	50	5.8
Sitanion longifolium	3.0	2.0	50	2.91
Juglans major	2.6	1.4	10	1.8
Bromus richardsoii	.95	.5	20	3.6
Verbascum thapsus	.75	.5	20	.97
Achillea lanulosa	.45	.3	200	.97

Table 4
Common Names from Cherry Canyon Transect

Genus	species	Common name
Muhlenbergia	montana	Mountain muhly
Parthenocissus	inserta	Virginia creeper
Thalictrum	fendleri	Meadow rue
Solidago	sparsiflora	Goldenrod
Sitanion	longifolium	Squirrel-tail
Juglans	major	Arizona Walnut
Bromus	richardsonii	Brome grass
Verbascum	thapsus	Mullein
Achillea	lanulosa	Yarrow

Table 5
Fifth Fort (E) Transect Data
Refer to Fig. 11
Total Vegetative Cover = 56.7%

Rank by cover Species	% cover total veg.	% cover total length	% freq.	Relative Density
Erigonum jonesii	27.33	15.1	50	8.33
Poa fendleriana	8.99	5.1	50	29.16
Astragulus humistratus	7.90	4.3	50	10.41
Heterotheca villosa	7.58	4.5	50	10.41
Yucca baccata	5.29	3	20	4.16
Artemisia dracunculus	1.76	1	20	8.33
Bouteloua gracilis	1.76	1	20	6.25
Artemisia frigida	1.23	0.7	10	2.08
Cercocarpus montanus	1.05	0.6	10	2.08
Opuntia fragilis	.88	.05	20	4.16
Echinocereus triglochidiatus	.88	.05	10	2.08
Penstemon jamesii	.70	0.4	10	2.08
Gutierrezia sarothrae	.52	0.4	10	2.08
Erigeron divergens	.52	0.3	10	2.08
Tragia stylaris	.17	0.1	10	2.08

Table 6
Common Names from Fifth Fort Transect

Genus	species	Common name
Erigonum	*jonesii*	Buckwheat
Poa	*fendleriana*	Mutton grass
Astragalus	*humistratus*	Milk Vetch
Heterotheca	*villosa*	Golden Aster
Yucca	*baccata*	Blue Yucca
Artemisia	*dracunculus*	Sagebrush
Bouteloua	*gracilis*	Blue grama
Artemisia	*frigida*	Sagebrush
Cercocarpus	*montanus*	Mountain mahogany
Opuntia	*fragilis*	Pricklypear
Echinocereus	*triglochidiatus*	Hedgehog
Penstemon	*jamesii*	Penstemon
Gutierrezia	*sarothrae*	Snakeweed
Erigeron	*divergens*	Fleabane
Tragia	*stylaris*	Noseburn

Table 7
Fifth Fort (W) Transect Data
Refer to Fig. 11
Total Vegetative Cover = 66.5%

Rank by cover Species	% cover total veg.	% cover total length	% freq.	Relative Density
Poa fendleriana	30.82	20.5	100	17.96
Erigonum bakeri	26.16	17.4	70	6.79
Heterotheca villosa	7.96	5.3	10	.97
Astragalus humistratus	7.36	4.9	60	5.3
Artemisia dracunculus	3.30	2.2	50	5.8
Penstemon jamesii	3.0	2.0	50	2.91
Petrophyllum caespitosum	2.55	1.7	10	1.4
Artemisia frigida	2.4	1.6	20	2.91
Cercocarpus montanus	1.50	1.0	10	.48
Gutierrezia sarothrae	.75	.5	10	.97
Bouteloua gracilis	.75	.5	10	.97
Berberis repens	.75	.5	10	.97

Table 8
Common Names from Fifth Fort Transect

Genus	species	Common name
Poa	*fendleriana*	Mutton grass
Erigonum	*bakerii*	Buckwheat
Heterotheca	*villosa*	Golden Aster
Astragalus	*humistratus*	Milk Vetch
Penstemon	*jamesii*	Penstemon
Petrophyllum	*caespitosum*	Rockmat
Artemisia	*frigida*	Sage
Cercocarpus	*montanus*	Mtn. mahogany
Gutierrezia	*sarothrae*	Snakeweed
Bouteloua	*gracilis*	Blue grama
Berberis	*repens*	Mahonia

Table 9
First Fort (N) Transect Data
Refer to Fig. 11
Total Vegetative Cover = 52.3%

Rank by cover Species	% cover total veg.	% cover total length	% freq.	Relative Density
Atriplex canascens	26.95	14.1	40	20
Erigonum jonesii	21.6	11.3	50	10.9
Brickellia grandiflora	9.2	4.8	30	7.2
Bromus tectorum	8.8	4.6	30	7.2
Heterotheca villosa	7.6	4.0	30	12.7
Artemisia dracunculus	7.1	3.7	20	5.4
Poa fendleriana	5.0	2.6	10	1.8
Sitanion longifolium	4.1	2.1	20	7.2
Opuntia fragilis	3.2	1.7	20	3.6
Chamaebatiaria millefolium	2.7	1.4	10	1.8
Sphaeralcea fendleri	1.52	.8	10	1.8
Bouteloua gracilis	.95	.5	20	7.2
Astragalus humistratus	.95	.5	20	3.6
Echinocereus triglochidiatus	.38	.2	10	2.4

Table 10
Common Names from First Fort Transect

Genus	Species	Common name
Atriplex	*canescens*	4-wing Saltbush
Erigonum	*jonesii*	Buckwheat
Brickellia	*grandiflora*	Bricklebush
Bromus	*tectorum*	Cheat grass
Heterotheca	*villosa*	Golden aster
Artemisia	*dracunculus*	Sagebrush
Poa	*fendleriana*	Mutton grass
Sitanion	*longifolium*	Squirrel tail
Opuntia	*fragilis*	Pricklypear
Chamaebatiaria	*millefolium*	Fernbush
Sphaeralcea	*fendleri*	Globe-mallow
Bouteloua	*gracilis*	Blue grama
Astragalus	*humistratus*	Milk vetch
Echinocereus	*triglochidiatus*	Hedgehog

Table 11
First Fort (W) Transect Data
Refer to Fig. 11
Total Vegetative Cover = 85.6%

Rank by Cover Species	% cover total veg.	% cover total length	% freq.	Relative Density
Chrysothamnus nauseosus	57.5	49.2	90	34.40
Bouteloua gracilis	30.75	26.5	80	39.4
Atriplex canascens	5.72	4.9	20	1.63
Descurainia pinnata	4.90	4.2	70	21.31
Oryzopsis micrantha	.81	.7	10	1.63
Penstemon virgatus	.11	.1	10	1.63

Table 12
Common Names from First Fort Transect

Genus	species	Common name
Chrysothamnus	nauseosus	Rabbitbrush
Bouteloua	gracilis	Blue grama
Atriplex	canascens	4-wing Saltbush
Descurainia	pinnata	Tansy mustard
Oryzopsis	micrantha	Rice grass
Penstemon	virgatus	Penstemon

Table 13
Island Trail Transect Data
Refer to Fig. 11
Total Vegetative Cover = 60.3%

Rank by Cover

Species	% cover total veg.	% cover total length	% freq.	Relative Density
Erigonum bakeri	26.55	15.3	50	8.23
Gutierrezia sarothrae	8.99	5.1	50	29.16
Poa fendleriana	7.80	4.5	30	10.41
Artemisia frigida	7.58	4.3	50	10.41
Bouteloua gracilis	4.27	3	20	4.14
Yucca baccata	1.76	1	20	8.33
Echinocereus triglochidiatus	1.05	.06	10	2.08
Cercocarpus betuloides	.88	.05	10	2.08
Opuntia fragilis	.88	.05	20	4.16
Broumus tectorum	.51	0.3	10	2.08

Table 14
Common Names from Island Trail Transect

Genus	Species	Common name
Erigonum	*bakeri*	Buckwheat
Gutirezia	*sarothrae*	Snakeweed
Poa	*fendleriana*	Mutton grass
Artemisia	*frigida*	Sage
Bouteloua	*gracilis*	Blue grama
Yucca	*baccata*	Blue yucca
Echinocereus	*triglochidiatus*	Hedgehog
Cercocarpus	*betuloides*	Mtn. mahogany
Opuntia	*fragilis*	Pricklypear
Bromus	*tectorum*	Cheat grass

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